SixDOF Sensor

U.S. Patent: 5,883,803

Introduction

The patented six-degree-of-freedom (SixDOF) sensor can be very useful in the fields of automation and manufacturing. Currently, many automated assembly lines rely on datum specification of different axes, requiring robots to be given information about specific orientations and/or location of parts. This results in very long set-up times that can reduce throughput and limit production capabilities of a plant's operation. The SixDOF sensor can be used to eliminate the cost of designing jigs and fixtures for specific positioning of parts in an assembly line by allowing robots to "see" the parts. The sensor's abilities directly improve flexibility, quality control, and consequently, production process yields, creating a manufacturing environment that is more efficient and profitable.

SixDOF sensor compared to the size of a quarter. The device consists of a laser with simple optics and position sensitive detectors (PSD's).

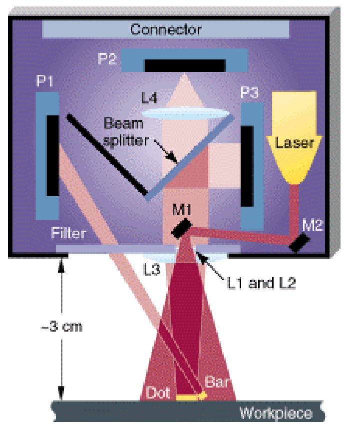
The SixDOF sensor makes robot manufacturing smarter, saving both time and money. This small, relatively low-cost, non-contact sensor that increases the capability and flexibility of computer-controlled machines by detecting the sensor's relative position to any mechanical part in all six degrees of freedom, using a laser sensor in combination with simple optics and position sensitive detectors (PSD's). The SixDOF sensor can be mounted on the tool head of a multi-axis robot manipulator to track reflective reference points attached to the part. Once the robot knows where it is relative to the part, a computer can then instruct the robot to follow a path predescribed in multidimensional computer drawings of the part, or the robot can be programmed to follow a path of references mounted on the part. The sensor eliminates the need for "training" the robot and enables process changes without halting production because software can be quickly downloaded in the robot's controller. The SixDOF sensor is estimated to be over 200 times faster and 25 times more accurate compared to current 3-DOF sensors. With simple inputs to the software, the device can easily be recalibrated, allowing for loose manufacturing tolerances, use of inexpensive plastic optics and housing, and operation under variable environmental conditions.

How Does It Work?

The SixDOF sensor is composed of four assemblies: a laser illuminator; beam splitting and directing optics; lateral-effect photo diodes; and signal-processing electronics. The laser source is a 5-milliwatt diode laser. Two small mirrors (M1 and M2 on the illustration) guide the 1-millimeter laser beam to the primary optical axis of the sensor. The beam then passes through two negative lenses (L1 and L2) that diverge the beam at about 0.3 radians. This high divergence creates a 2-centimeter laser spot at about 3.5 cm from the face of the sensor. The beam divergence, depth of field and spot size can be changed by choosing different negative lenses.

The laser beam reflects off a target consisting of a 4-millimeter dot adjacent to a 1-by-1-mm tilted bar (alternatively, both can be incorporated into a hologram attached to the object of interest) and returns to the sensor. Because the beam is diverging, the reflections are magnified in area when the light returns to the sensor, allowing most of the light to go around the negative lenses and through a large, collimating lens (L3) instead. After collimation, the beam continues through a notch filter, which passes the laser light and blocks light at other wavelengths.

Inside the sensor, the light from the dot is divided into two beams by a beam splitter. Half of the beam is reflected 90 degrees onto a photo diode (P3). The other half of the beam passes through the beam splitter, into a focusing lens (L4), and onto a photo diode (P2). The light from the second reflective surface, the bar, also passes through the filter. However, because this reflective bar is tilted relative to the dot, the laser light reflecting from it is at a greater angle of divergence. The greater angle causes the light to pass through a different location of the filter, missing the collimating lens and illuminating another photo diode (P1).



Internal schematic view of the SixDOF sensor.

Through creative use of mirrors and lenses, each of the three photo diodes has a different sensitivity to the relative position of the sensor and the reflectors. P1 is the most sensitive to straight-line motion between the bar and the sensor (z), and the rotation of the sensor about that axis (Rz). P2 is most sensitive to tilt about the x and y axes (Rx and Ry), and P3 is most sensitive to straight-line motion of the sensor relative to the reference dot (x and y). Information from the three sensors is used to determine all three position and three orientations of the sensor relative to the part.

The signals from the three photo diodes are processed by electronics remotely located from the sensor head. The analog data from the diodes are digitized and fed into a computer where they are decoupled to define the six axes of information. The processed data can then by used by the operator for recording or sending commands to change the position of a computer-controlled machine.

Some Potential Applications

Manufacturing – The SixDOF sensor will likely find its greatest use in manufacturing where highly agile and accurate machines have been limited by their inability to adjust to changes in their tasks. If enabled to sense all six degrees of freedom, these machines would be able to adapt to new and complicated tasks without human intervention or delay.

Aviation Quality Control – The vibration modes of an aircraft's wings could be easily monitored with SixDOF sensors. The same principle can be applied to the aircraft's turbine blades. Misalignment of any particular blade is also possible to detect using the SixDOF sensor.

Computer – The SixDOF sensor would allow a user to perform much more complicated tasks than are possible today with a typical two-degree-of-freedom mouse.

Robotic Surgery – The SixDOF sensor would provide the surgeon with a powerful sensing tool to assist in surgeries where the surgeon manipulates a robotic arm. SixDOF sensors could be used to report information on the position and orientation of the robotic arm.

Medical Rehabilitation – The sensor could be used to help doctors diagnose muscle recovery by evaluating the effects of physical therapy. With reflective reference points mounted on a patient's injured limb, a robot with a SixDOF sensor could generate a SixDOF map of muscle motions.

Hazardous Materials (HAZMAT) Handling – The sensor could also be used for dangerous tasks remote from the operator such as manipulating radioactive, toxic, or explosive materials. For example, a robot with a SixDOF sensor could track relative references mounted on the hands of an operator who disassembles a dummy bomb while another robot, electronically following the motions of the first robot, disassembles the real bomb.